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ABSTRACT

This chapter describes current research in cognitive psychology and considers how this work may be applied to the design of instructional materials. The nature of knowing--and of meaningful knowing--are examined, and findings from psycholinguistics and pattern recognition are integrated to provide an understanding of concept and memorization learning. It is suggested that meaningful learning involves the relating of new content to previously learned content or previously integrated experience. Suggestions are made for the design of instructional materials to bring about such meaningful learning. Three figures are provided. (26 references) (Author/EW)

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Chapter 11

Knowledge and Its Acquisition: An Introduction and Overview

Buford E. Wilson

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How is knowledge defined? How is it acquired? What must instructional developers know about these topics if they are to be competent designers of instruction? Do the answers lie in experimental psychology? behavioral psychology? cognitive psychology? How greatly do individuals differ in their abilities and approaches to the acquisition of knowledge? This chapter analyzes these questions and provides some guidelines for IDers which should aid them in the design of instruction.

KNOWING

Over the past fifteen years literature in the psychology of learning has shown a renewed interest in mental processes. Concerns with mental representations of external events and the cognitive processing of information are now central issues in the study of human learning (e.g., Neisser, 1967; Bower, 1975).

A new and exciting conception of human learning is emerging from this resurgence of interest in cognitive psychology. This new characterization is founded in experimental psychology, but has its historical and theoretical roots in Gestalt psychology and in the psychology of humans, which existed in Europe early in this century (Bartlett, 1932; Humphrey, 1963). It is, consequently, a radical departure from the conceptions of learning derived from behavioral psychology. In this chapter I will attempt to give the reader an overview of this new conception and discuss some of its basic implications for the design of instruction and instructional material.

As a way of beginning to think about your knowledge of the world, think of your house or apartment. Close your eyes and imagine yourself in your living room. How many windows are in that room? Now, move on the kitchen. How many windows are there? Proceed through the rest of the house counting windows. How many windows are there in total? If you have lived in your present home for any time at all, the task of counting the imaginary windows is not difficult. This simple mental task illustrates the power and usefulness of our knowledge of the world. Most people have not counted windows in their homes. It is not a fact that has been memorized, but our ability to recreate and manipulate mentally parts of our world allows us to solve this problem easily.

Our knowledge allows us to represent to ourselves things and events which are not present. It allows us to manipulate these objects and events mentally in order to solve problems, or to imagine possible problems. For example, what problems might you encounter if you decided to move a piano into your home? What changes or special arrangements would be necessary before such a

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move was possible? Depending upon your home and your imaginary piano, you might have problems related to narrow stairways, small doors, or high balconies. The point is, that your knowledge of the world allows you to represent to yourself parts of the world which are not present. Additionally, it allows you to manipulate and change these representations in order to anticipate and solve problems. You can imagine solutions such as moving walls or taking out windows and decide if they are practical solutions, or actions which would cause more trouble than they are worth. This chapter will provide a general characterization of knowledge and the process of knowledge acquisition.

Many of our everyday assumptions about knowledge are incorrect. One such assumption is that our knowledge of the world is based upon copies or replicas of our experiences. It seems natural and correct to assume that we know what it was that we did yesterday because we somehow made copies of what we experienced. Sometimes we can't remember all of what happened. This forgetting, it is assumed, occurs because our copies of our experiences have become weak, distorted, faded, or mixed with other copies and therefore have become hard to recover. This set of assumptions about the nature of knowledge and its acquisition has a long history in philosophy (Ackerman, 1965) and psychology (Boring, 1950). In fact, it is an important theoretical underpinning of the behavioristic psychology which dominated American psychology for 50 years.

As we shall see, however, our knowledge of the world is not based upon faded or distorted copies of reality, and we do not acquire knowledge by making and storing copies of what we experience. Consider once again your knowledge of your home. As the counting-windows task demonstrated, you do have a great deal of useful knowledge about your home. This knowledge, however, is not like a copy or replica of things in the world. It is much more like a general outline or schematic representation. Most people can easily draw a rough outline of their home, including placement of furniture, windows, stairways, etc. This ability depends upon knowledge of their home and of the objects in it. While our knowledge allows us to generally characterize our world, it rarely contains the detail or specificity contained in a copy or photograph. Details of color, size, shape, or orientation frequently are not included in our knowledge of very familiar things. This would not be so if our knowledge was based upon mental copies of our experiences.

Consider the couch in your living room, presumedly an object with which you are familiar. What is its color and shape? If it has a pattern or design, try to draw this pattern. If not, try to draw its shape exactly. How do the cushions and arms articulate with the back of the couch? When you try to reproduce details of the objects and events in your world, you find that the task is difficult even for familiar objects.

What object could be more familiar to modern man than the telephone? Most of us use the telephone daily. Children play with toy telephones. Yet upon close examination, our knowledge of the telephone is not as detailed as we would expect. Which letters are on the telephone dial? Which letters are not? Which letters are by the numeral 1? Most people don't know which letters of the alphabet are not on the dial, and most people do not know which letters are by which numerals. In fact, the letters Q and Z are not on the telephone dial. Further, the numerals one and zero do not have letters accompanying them. Clearly, we do not have the detailed knowledge that would be expected if we were able to copy and store our experiences of the telephone. We do, however, have a great deal of useful knowledge about the telephone. We know the general shapes it can take. We know which way the dial turns, where to speak and where to listen. In short, we have the knowledge necessary to operate the telephone. It is important to see that while your knowledge is not a copy of reality or of your experiences it is a useful and coherent representation of those parts of the world with which you interact. You are able to move successfully from place to place, find solutions to problems which arise, and predict and understand many objects and events with which you interact.

Psychologists have documented in many different situations our ability to gain useful knowledge from our experiences even though we are unable to recount or recreate those experiences exactly. It is useful to examine some of these situations in order to begin to understand the nature of the knowledge we gain from our experiences.

In psycholinguistic studies, researchers have found that subjects frequently acquire a correct representation of the meaning of sentences, but do not acquire knowledge about the exact form of the sentence. For example, they may fail to remember if a sentence was presented in the active or passive voice even though they can remember the information presented in the sentence (Mehler, 1963; Slobin, 1968). The physical difference between "John hit the ball," and "The ball was hit by John" is considerable, but the information conveyed is indeed similar. The subjects seemed to acquire a correct abstract or general representation of the meaning of such sentences without acquiring a copy of what was actually experienced. A similar result was reported by Sachs, (1967) who found that subjects readily detected changes in sentences they had previously read if the changes altered the meaning of the sentences. However, subjects had great difficulty detecting changes in the sentences which left the meaning unaltered.

This ability to acquire abstract representations from our experiences is not limited to language phenomena. Jenkins, Wald, and Pittenger (1978) reported a similar finding when subjects were shown photographs of a woman making tea. In this study, 24 photographs were taken depicting

the various steps involved in the preparation of tea. Sixteen of these 24 pictures were shown in the acquisition phase of the experiment. Later, these 16 pictures, plus the remaining 8 from the original set, were shown to subjects, who were asked to indicate whether each picture was new or was one which had occurred during acquisition. Subjects were unable to distinguish the new but appropriate pictures of the event from the pictures which they had actually experienced during acquisition. The subjects had acquired an abstract representation of the event but not copies of pictures actually experienced.

Posner and Keele (1968) found that when given experience with classes of patterns, subjects acquired abstract representations which allowed them to correctly classify novel instances of those classes. Figure 11-1a shows the prototype (original) and 5 other instances of the class triangle. Figure 11-1b shows the prototype of the other classes.

After experience with the distortions from these categories, subjects were able to recognize new distortions and the prototype patterns even though these instances had not been seen before. Later, Posner and Keele (1970) concluded that while the conceptual system which allowed subjects to correctly classify novel instances of the classes of patterns was gained from experience with the class of patterns, this conceptual system was not derived from stored copies of those patterns. This conclusion was based upon the fact that one week after the original experience with patterns the subjects' ability to classify the patterns originally seen had decreased, while their ability to classify the new prototypic patterns had not. These results demonstrate that the subjects were in fact acquiring knowledge which allowed them to classify correctly novel instances of patterns, but that this knowledge was not based upon stored copies of the original patterns. If the ability to classify new patterns was based upon stored copies of the original patterns, the ability to classify the new patterns would decrease as the knowledge of the original patterns decreased. In fact, decreases in ability to identify the patterns seen during acquisition did not cause decreases in subjects' ability to recognize the new patterns. This demonstrates that the ability to classify novel patterns was not based upon stored copies of the original patterns.

Franks and Bransford (1971) demonstrated that while subjects could acquire a rule system concerning relations between geometric forms, they were poor at distinguishing instances actually seen during learning from instances which fit the rule system but had not been seen before. That is, the knowledge acquired was knowledge of a system, not copies of specific cases. Reed (1972) found similar results with subjects learning to categorize simple drawings of faces.

These studies show that across a wide variety of situations what is learned is an abstract representation of the objects and events that we experience. They also show that these abstract representations are not based upon our ability to store copies of our experiences. Our knowledge is an abstract or general representation of our world, and not a copy of the world or of our experience of it.

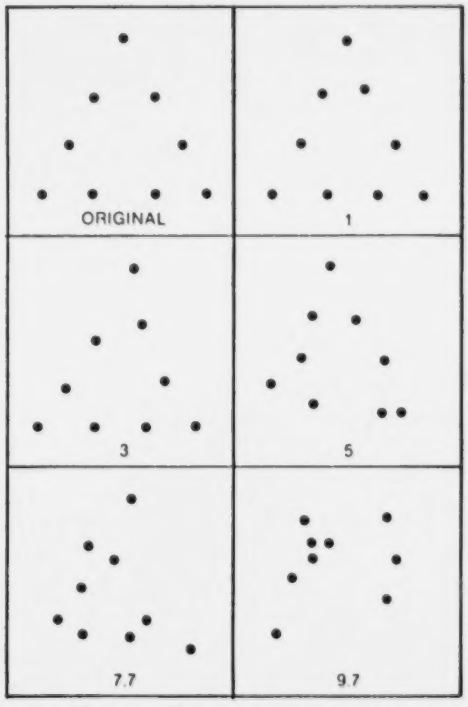

Figure 11-1a. The prototype and five levels of distortions for the set of triangles.

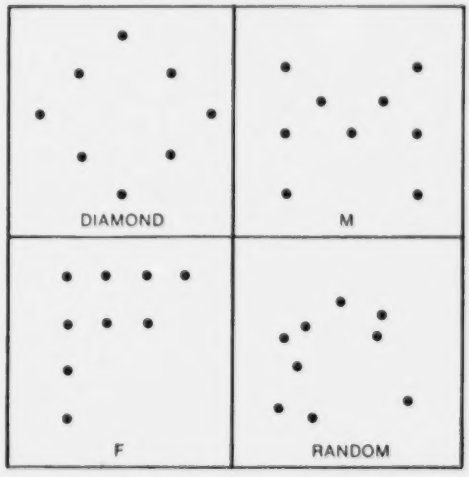

Figure 11-1b. Prototypic patterns of other sets: diamond, M, F, and random.

These abstract representations are not a result of copies of our experiences which have become faded or distorted. Faded or distorted copies of our experiences would not reliably provide us with accurate characterizations of objects and events. A Polaroid picture which has not finished developing is like a faded copy. The underdeveloped print does not reliably capture the objects and relationships in the picture. Facial features, parts of peoples' bodies, and even whole objects may not appear until the picture is fully developed. The faded copy does not contain the information necessary for a general representation of the objects and events in the picture. Similarly, distorted or damaged copies may not contain the information necessary for such a representation. Consider a schema of the floor plan of a house. If ink is spilled upon the floor plan a complete room could be covered, or a fireplace or a window completely hidden. The distorted copy would therefore no longer be an accurate characterization of the floor plan.

As we saw earlier, subjects in psycholinguistic studies frequently recall the meaning of sentences but are unable to remember if the sentence was originally experienced in the active or passive voice. We want to make two important points about these findings. First, faded or distorted copies of the sentence, "The ball was hit by John." would result in the loss of some of the words or letters in the sentence. Such a loss of items would often change or distort the meaning. For example, if "by" was lost we might, at the time of recall, mistakenly substitute "to" in its place, producing "The ball was hit to John." If the "b" in "ball" was faded or distorted or partially faded or distorted we might mistakenly remember "The wall was hit by John." Many errors could occur which would change or destroy part of the meaning of the sentence. These types of errors did not occur in the studies we reported. In fact, subjects retained the meaning of the sentences when the form in which the sentence occurred was lost. It seems implausible that the subjects' memory for the meaning of the sentences was based upon faded or distorted copies of the sentences.

The second point is that if the subjects' knowledge of the sentences was in the form of copies of the sentences, considerable fading or distorting would have to occur to cause

"The ball was hit by John,"

and

"John hit the ball,"

to be confused with each other. Physically, the sentences are quite dissimilar. The order and position of the words is different in each case and the passive voice contains two more words than the active voice. If enough distortion or fading occurred to make the copies of the above two sentences indistinguishable the copies would no longer convey the meaning of the sentences.

Both of these points demonstrate that the subjects' knowledge of the sentences cannot be derived from faded or distorted copies of the sentences actually experienced. These two points can also be applied to the studies we discussed above. That is, it can be shown that the subjects' knowledge of sentences (Sachs, 1967), random dot patterns (Posner and Keele, 1970), rule systems (Franks and Bransford, 1971), drawings of faces (Reed, 1972), and a tea-making event (Jenkins and Wald, 1979) cannot be explained on the basis of faded or distorted copies of items experienced during learning.

An attempt has been made to show that our knowledge of the world takes the form of abstract or general representations of the objects and events we experience. An argument has been presented that on the one hand our knowledge does not have the detail or exactness found in copies and on the other that faded or distorted copies cannot provide an adequate basis for the knowledge we have about our world.

If we do not copy our experiences and use these copies as the basis of our knowledge, how do we gain knowledge about the world? Clearly, experience with the objects and events in our world is important and we do gain information from these experiences. What, then, is the relation between our experiences and our knowledge of the world?

Before the advent of behaviorism, the problem of the relation of experience and knowledge was seen as important by psychologists studying learning. The rebirth of interest in cognitive psychology has brought with it a renewed interest in the relation of experience and knowledge. A basic insight shared by those interested in this problem is, that new learning presupposes some knowledge-structure to which the new information can be connected or related. If we are not able to copy our experiences we must have some way to relate our experiences to existing knowledge. Norman (1969) states, "for something to be learned or remembered it must be integrated within the existing organization of knowledge." Bower (1975) states "In characterizing learning, one is interested in...how that information comes to be represented and related to other things as it is stored in long-term memory" and "the learning of a new fact or concept is solely a matter of recording its representation, which is in terms of a specified configuration of relations among already-known concepts." These authors are acknowledging the fact that we can only understand something in terms of what we already know.

Piaget (1954) has brilliantly described how children conceptualize the world differently than do adults and how this knowledge leads them to interpret or understand their experiences differently than adults do. Infants will, when first given a rattle, put it in their mouth. They only gradually learn to shake the rattle to make a noise. At first, they understand or know the rattle in terms of its feel and shape as determined by their mouth and tongue. The acts of sucking, tasting, and feeling objects with their mouth are an important part of the infant's knowledge of the world. Consequently, they will gain knowledge about a rattle that most

adults would not. The infant will probably learn about tastes of plastic or glue from their experiences and they will feel indentations or scratches that we might not notice. They are understanding the rattle in terms of what they already know. They are not copying their experiences, they are interpreting them in terms of the knowledge they already have. They do not have adult knowledge which would allow them to say, "it is a pink and blue hollow sphere with little bits of rock inside." Notice, however, that they are acquiring knowledge about the rattle, knowledge which is useful to them. They use this knowledge to create or build general representations of the objects and events in their world. Their knowledge of the world is very different from ours, and therefore the knowledge they gain about the rattle will in turn be different. The meaning they create will be different from the meaning we would create.

The act of interpreting what we are experiencing in terms of what we already know is the basic process of knowledge acquisition, i.e., learning. This use of existing knowledge to make sense of current experiences can take many forms ranging from simple recognition or verification of something already known to the actual creation of new knowledge. Consider the following three examples as points along this continuum. Often we assimilate current experiences into our existing knowledge. This is a chair. This is a blackboard. This is the number 3. In these cases the experience is related to existing knowledge with little readjustment or use of the existing knowledge. At other times we make sense of our current experiences by using or readjusting our knowledge. For example, researchers frequently ask subjects to discover patterns or regularities. Katona (1940) asked subjects to discover the principle which related the numbers in Figure 11-2. Solving this problem involves the use of existing knowledge, e.g., knowledge of numbers, puzzles, and possible relationships, to look for regularities and test possible solutions. We will discuss Katonas' problem and its solution again later in this chapter. Whitman and Garner (1962) presented subjects with lists of geometric forms which were related by rules. For example, the four binary attributes, one or two, large or small, red or blue, and circles or squares, can be used to generate 16 possible geometric forms. Subjects were given 8 of these 16 forms as an acquisition set, i.e., memory set. Discovering the rules distinguishing forms in the memory set from forms not in this set would enhance the subjects' ability to recall the geometric forms. That is, they could use the rules to generate the possible forms in the memory set. Remembering the rules would be easier than remembering all of the instances. Whitman and Garner found that subjects were able to discover the rules relating the forms in the memory set. The difficulty of recall in their experiments depended directly upon the complexity of the rule relating the forms in the memory set.

In the studies by Katona (1940) and Whitman and Garner (1962) the subjects used their existing knowledge to discover a rule or regularity existing in their experiences. Finally, consider an instance in which we use our existing knowledge to make sense of current experiences by actually creating new knowledge. Suppose that we already know how to compute the area of a rectangle. It follows that half of this area would be the area of half of the rectangle. Now suppose that you were drawing right triangles and notice that they were always one-half of a potential rectangle. Suddenly, it occurs to you that you can compute the area of the right triangle by computing the area of its potential rectangle and dividing by 2. You have used your existing knowledge to create new knowledge. You have created new knowledge to make sense of your current experiences. This is not an unusual use of your knowledge. Imagining the difficulties of moving a piano in your home also involved the creation of new knowledge, i.e., knowledge of difficulties or solutions you had not considered before. This ability to generate novel thoughts and actions is a basic attribute of human knowledge. What we know and remember are the products of these mental activities, by which we make sense of our current experiences. The child who believes that the moon is following him, or that the number of items in a row can be changed by simply stretching out the row (Piaget, 1954) is learning something quite different from what we might learn from the same experiences.

Similarly, the knowledge gained at a ballet or basketball game by a serious fan and by a novice will be strikingly different. These two types of observers have different knowledge about the events they are watching, and consequently the meanings of the events will be vastly different. That is, the experiences will be related and integrated into different knowledge structures. The novice will have little knowledge of the strategies or patterns of movement involved. He probably will not see or remember subtle interactions which have a tremendous importance to the experienced observer. The knowledge that we bring to a set of experiences will have a tremendous effect upon what we learn from those experiences.

Degroot (1965) and Chase and Simon (1973) report that, as you might expect, master chess players are much better at remembering sequences

Figure 11-2. Array of digits used by Katona, 1940. See text for explanation.

2 9 3 3 3 6 4 0 4 3 4 7

5 8 1 2 1 5 1 9 2 2 2 6

of moves and positions of pieces in chess games than are novice players. This makes sense because master chess players are able to integrate individual moves into their knowledge of strategies and counter-strategies. Chess masters frequently are able to recall large sequences of moves correctly. If, however, the masters are requested to try to remember random (meaningless) changes in the position of the chess pieces they are not superior to the inexperienced player. The chess master who cannot relate the position of the pieces to his knowledge of strategies and plans is in the same position as the novice who has very little knowledge of strategies or plans. In both cases understanding and remembering the moves involved in a game is dependent upon being able to make sense of the current experiences in terms of existing knowledge. The novice is unable to remember long sequences of mores because he does not have much knowledge which enables him to see or understand these sequences as coherent, meaningful patterns. The master is in the same position as the novice when the moves are random, i.e., he cannot relate the individual moves to his knowledge of strategies and counter-strategies. What is learned is the product of the mental activity of relating and interpreting current experiences in terms of existing knowledge. When the master is unable to relate experiences of the changes in positions of the chess pieces to existing knowledge, this great wealth of knowledge is of little use.

We have described knowledge acquisition as the process of interpreting current experiences in terms of existing knowledge. Now we will turn to a consideration of two implications of our characterization of knowledge acquisition. The first implication is that existing knowledge is a strong determiner of what is learned from current experiences. The second is that current experiences can be related to existing knowledge in many ways, thereby producing different types of knowledge. Consider the first implication. A non-English speaking listener does not have the knowledge necessary to allow him to understand this sentence. He would be unable to use his existing knowledge to make sense of his experience of the sentence. Depending upon his existing knowledge s/he may or may not know that marks on the paper are some form of communication. It is even possible that s/he could have knowledge which allowed her/him to understand that the words are English words but still not know what the words mean. These examples make the simple point that understanding and learning are strongly determined by what you already know.

Consider the list of words in Figure 11-3. This list is made up of words from four categories: spectator sports, occupations, fuels, and geological formations. Each of the categories contains five words, making a total list of twenty items. With the knowledge that you will be asked to remember this list, read it through one time slowly and out loud at the rate of about one word every 5 seconds.

Figure 11-3. Categorized word list and a typical recall protocol for that list.

WORD LIST	RECALL PROTOCOL
football	golf
mountain	football
oil	hockey
doctor	carpenter
gas	lawyer
baseball	doctor
teacher	valley
valley	cave
kerosene	mountain
dentist	wood
river	oil
wood	gas
basketball	kerosene
lake	river
nurse	
hockey	
butane	
carpenter	
cave	
golf	

Now close the book and write down as many of the words as you can remember. Write them down in the order that they come to mind. Allow yourself two or three minutes to recall as many of the words as you can.

When you examine what you were able to remember, two things are immediately apparent. You can remember a large number of the words in the list, and your recall is organized in terms of the categories in the list. Figure 11-3 contains a typical recall protocol.

Consider first the amount of recall. With a little practice with such lists most people are able to remember 15 or more of the words. This is an unusually large amount, but it is typical of the

recall of word lists made up of familiar categories. Psychologists have shown that lists made from familiar categories are remembered much better than comparable lists of unrealted words (Bower, 1970). Your existing knowledge of the categories, occupations, etc., allows you to form the words in each category into a mental group. This grouping of the words in terms of your existing knowledge makes it easier to recall the items on the list. You are able to form four mental groups for recall instead of trying to recall twenty separate items. If you didn't have prior knowledge of a particular category, this advantage would be lost for that category. If you had no knowledge of any of the categories, then your recall would not be aided at all by the categorized list and would be no better than the recall of twenty unrelated words.

Next, consider the order in which the words were recalled (See Figure 11-3 for a typical recall protocol). The words tend to be recalled in groups of items from the same category even though words from the same category did not occur together in the actual list. Compare the order in which the words were presented and the order in which they were recalled. The subjects' knowledge of the words they experienced is organized in terms of their existing knowledge.

In fact, most peope have almost no knowledge of the order in which the words actually occurred. What word occurred before doctor? What word followed lawyer? These are hard questions, but "what are some other occupations?" is not difficult to answer. Suppose we were given the task of memorizing a long list of names. The fact that this list was made up of dancers and of baseball players from the 19th century would be of little help to most of us. That is, these categories probably would not affect the amount or the organization of what we learned. However, to students of dance and baseball this structure in the list could be extremely helpful. As the work on categorized word lists has shown, existing knowledge can determine both the amount and organization of what is learned from current experiences.

Earlier, we used DeGroot's (1965) and Chase and Simons' (1973) studies of chess masters to illustrate that gaining knowledge entailed making sense of current experiences in terms of existing knowledge. A comparison of the master and novice also demonstrates the role of existing knowledge in determining what can be acquired with current experiences. The existing knowledge of the chess masters enables them to make sense of long series of moves in terms of strategies and counter-strategies. The novice who does not possess this extensive knowledge is unable to relate the sequence of moves to existing knowledge. The novice is left with the unmanageable task of remembering the individual moves as many unrelated instances.

As an example of the second implication, consider the English word "now." We can relate the physical event of the word to our knowledge in many different ways and produce different types of knowledge. We can consider it as a sound and notice that people with different accents pronounce it differently. We can consider it as a physical object and learn that it is longer or shorter than our first name. We can consider it as an answer to the question, "When do we eat?" or a command, "Not later, now!" It is possible to create a seemingly endless number of ways of relating this event to our existing knowledge, e.g., it is made up only of letters from the last half of the alphabet. We can go on and on finding new ways to relate or interpret the event "now" in terms of our existing knowledge. These different mental activities frequently produce different knowledges. We might pay attention to someone's accent and miss part of what they say, or notice the shape of letters during handwriting analysis and not the known words or word meanings of the materials we are analyzing.

In 1932 Edward Thorndike reported a series of experiments investigating the relation of external and mental events. Specifically, he wanted to know the effects of repetition upon the nature of mental representations. In a typical study his subjects were given the following instructions: "I shall read you a long list of pairs or words and numbers like 'bread 29,' 'wall 16,' 'Texas 78.' You will listen as I read them. Pay about as much attention as you would in an average class. Be sure that you hear each pair as I read it." Notice that the instructions lead you to build mental events made up of pairs. That is, you relate 'bread' and '29' in your mind. Similarly, you are asked to relate 'wall' and '16.' You are requested, however, to relate '29' and 'wall.' If these pairs always occur together in the order 'bread 29,' 'wall 16,' '29 and wall' occur together as often as 'bread' and '29,' or 'wall' and '16.'

Thorndike wanted to know what effect the repetition of '29' and 'wall,' one after the other, would have upon mental constructions. Would the repetition of the items cause them to be related in the subjects' knowledge of the lists? Thorndike found that in cases like this, even though the items occurred together 24 times during the experiment, subjects still had no knowledge of the relationship. The average percentage of correct responses for these items was 1/2 of one percent! In contrast, subjects were able to correctly respond to the intended pairings 38 percent of the time. Even when repeated 24 times, the pairing of '29' and 'wall' did not automatically become part of the subjects' knowledge. Even with many repetitions, the mental events did not become replicas of the external events. Once again, the mental activity of the learners (the formation of pairs) was more important to learning than the structure of external events. In the same work, Thorndike reports the results of a similar study conducted by another psychologist, Van Der Veldt, in which nonsense syllables were paired with hand movements. The correct ordering of the pairs was not learned after 2,490 trials. The manner in which we interact with the events and objects in our world is indeed a strong determiner of what we gain from

these experiences. And the structure of the external events is not necessarily a good predictor of the structure of these mental constructions.

In the Thorndike experiments on belongingness, some relationships were not learned by any of the subjects even though the relationships were repeated many times. Now we wil turn to a situation in which everyone learns the items perfectly after very little practice. In Plans and the Structure of Behavior, Miller, Galanter, and Pribram discuss the following technique for remembering ten items and their order of occurrence.

> One evening we were entertaining a visiting colleague, a social psychologist of broad interests, and our discussion turned to Plans. "But exactly what is a Plan?" he asked. "How can you say that MEMORIZING depends upon Plans?
>
> "We'll show you" we replied. "Here is a Plan that you can use for memorizing. Remember first that:
>
> one is a bun,
> two is a shoe,
> three is a tree,
> four is a door,
> five is a hive,
> six are sticks,
> seven is heaven,
> eight is a gate,
> nine is a line,
> ten is a hen."
>
> "You know even though it is only ten-thirty here, my watch says one-thirty. I'm really tired, and I'm sure I'll ruin your experiment."
>
> "Don't worry, we have no real stake in it." We tightened our grip on his lapel. "Just relax and remember the rhyme. Now you have part of the Plan. The second part works like this: When we tell you a word, you must form a ludicrous or bizarre association with the first word in your list, and so on with the ten words we recite to you."
>
> "Really, you know, it'll never work. I'm awfully tired," he replied.
>
> "Have no fear," we answered, "just remember the rhyme and then form the association. Here are the words:
>
> 1. ashtray
> 2. firewood
> 3. picture
> 4. cigarette
> 5. table
> 6. matchbook
> 7. glass
> 8. lamp
> 9. shoe
> 10. phonograph."
>
> The words were read one at a time and after reading the word we waited until he announced that he had the association. It took five seconds, on the average, to form the connection. After the seventh word he said that he was sure the first six were already forgotten. But we persevered.
>
> After one trial through the list, we waited a minute or two so that he could collect himself and ask any questions that came to mind. Then we said, "What is number eight?"
>
> He stared blankly, and then a smile crossed his face; "I'll be damned," he said. "It's 'lamp'."
>
> "And what number is 'cigarette'?"
>
> He laughed outright now, and then gave the correct answer. "And there is no strain," he said, "absolutely no sweat."

In this technique for remembering, the learner builds a mental construction containing the to-be-remembered word and a word that rhymes with the to-be-remembered word's position in the list. This technique provides a way of interacting with the to-be-remembered word which guarantees that a mental construction appropriate to the memory task is built; that is, a mental event which contains the information that you will need later, i.e., the word and its position. The rhyming word relates the mental image to the learners' existing knowledge of the numbers 1 through 10. When the image containing the word and the rhyme is built, memory for the word and its position in the list is virtually assured.

These two learning situations, i.e., pairing words with numbers, and learning using a mnemonic technique, taken in conjunction, demonstrate the importance of the mental activity of the learner. It is the nature of the mental activity of the learner that determines what is learned. The external structure may or may not be reflected in the products of these mental activities.

In summary, human knowledge has been characterized as an abstract representation of the objects and events we experience. Knowledge acquisition was described as the act of interpreting current experiences in terms of existing knowledge. Finally, knowledge was described as the products resulting from the mental activities involved in relating current experiences to our existing knowledge. Let us now turn to a consideration of implications of this point of view for the design of instruction and of instructional materials.

APPLICATIONS TO INSTRUCTION

When we move about in the world, meeting people, doing our jobs, going here, going there, we are constantly acquiring knowledge. Most things we do give us new information: her name is Linda; to get there you turn right on Crawford; it rained yesterday; the Bears beat the Rams. We gain knowledge from almost all of our experiences. A basic concern for those of us interested in instruction and in instructional materials is exactly how we gain this knowledge. That is, what conditions are required in order for learning to occur? Some experiences seem almost automatically to lead to learning, while at other times something can be repeated over and over and still leave us unaffected or confused. Simply having an experience is no guarantee at all of learning.

When learners have appropriate existing knowledge and the current experiences are easily related to this knowledge, learning can be quick and effortless. Indeed, many of these experiences we do not consider as learning. We don't consider it learning to have noticed that an attractive person walked into the room, or to hear that our favorite team miraculously won another close one. These are, however, facts which are being acquired, things we are learning from interacting with our surroundings. When we read a novel, watch a movie, or have an intimate conversation with a friend, we are acquiring immense amounts of information. Yet, this learning usually seems effortless and occurs without conscious intent on our part to remember what we are experiencing.

In this section, we will consider how better to arrange instructional situations so that learning is a natural product of experience and not a forced or artificial task. As we saw in the first section of this paper, knowledge acquisition is not a process of producing copies or replicas of our experiences. Rather, learning was shown to be a process of interpreting current experiences in terms of our existing knowledge.

The relationship between the material to be learned and the existing knowledge of the learner is crucial in the design of instruction and of instructional materials. Acordingly, the first implication for instruction is that the instructional situation must be designed so that the learner is able to make sense of the instructional materials in terms of their existing knowledge.

This is not to say that humans are unable to learn things by rote, i.e., build mental copies, or that learning things by rote is never useful. It is to say, however, that learning by rote is not the natural or usual way we acquire knowledge about our world. Further, the knowledge we gain from rote learning is not the natural or usual type of knowledge we acquire.

If we reach back into our childhood, most of us have access to a poem, a speech or a document which we were forced to learn by rote. For example, most people can complete the phrase, "Four score and seven years ago..." Most of us memorized parts of the Gettysburg Address, but in doing so we learned little about the relevance or meaning of that speech. We can say parts of it upon request, but years may pass without the speech being brought to mind. It sits in our minds year after year having little meaning for us and offering no help in understanding our thoughts or experiences. It does not draw our attention to similarities between the issues and events of our times and the issues and events of the time for Mr. Lincoln. It does not cause us to notice similarities between the feelings and conflicts which we feel and the feelings and conflicts which Mr. Lincoln might have felt. And it is not a source for the understanding of books or movies about the Civil War. In fact, for most of us, the speech does not come to mind at all unless we are properly cued, as, for instance, by the line, "Four score and seven years..."

We are in a situation similar to that of the second graders who can say, "two plus two equals four", but who do not know how many oranges there are if they have two and a friend has two. They can correctly recite "two plus two equals four" when appropriately cued, but they do not understand how this recitation relates to objects and events in their world.

When we learned to recite the Gettysburg Address we did not make sense of it in terms of our existing knowledge. That is , we did not relate the contents of the speech to our knowledge of history, the United States, decision making, etc. As this example shows, meaningful and useful learning does not occur automatically with the building of mental copies. Instructional strategies and materials must lead the learner to understand (figure out) how the learning materials are relevant to the objects and events of their world.

How, then, should we proceed to arrange instructional activities and materials so that the learner is lead to use his existing knowledge to build mental representations which are more useful to him than would be mental copies?

Two basic conditions must be met before the learners will be able to accomplish this task. The first condition is that the learners must have background knowledge which will allow them to make sense of current experiences. For example, multiplication is a prerequisite for long division. You simply cannot understand long division until you are able to multiply. Similarly, without knowledge of phonetics, it makes little sense to identify "now" as a nasalized stop and diphthong vowel.

The second condition is that learners be directed toward mental activities which entail making sense of learning materials in terms of existing knowledge. William James (James, 1899) tells the story of visiting a friend's classroom and asking the children the following question. "If you dig a hole deeper and deeper into the earth, would it get hotter or colder as you went deeper?" The children did not know the answer to James' question. The instructor, hearing the interchange, said, "Oh, they know. Class, the center of the earth is

in a state of..." and the class responded, "igneous fusion." Children in the second or third grade do have the background knowledge necessary to understand that the earth is spherical in shape with molten rock in the middle of the sphere. And consequently, they could deduce that it would get warmer as your approached the center. The children have the prerequisite knowledge required by our first condition, but they were not led to use this knowledge to make sense of their instructional experiences, i.e., our second condition.

Similarly, most seventh-grade students have the background knowledge necessary to make some sense of the Gettysburg Address. The problem is to get them to use this existing knowledge to build the relevant constructions. Suppose we wanted students to learn that the Civil War was fought to preserve the basic values upon which our country was founded. Understanding such a statement involves (1) having knowledge of the basic values referred to, and (2) knowing that these values and our country itself might not exist in their present form if the Union had lost the Civil War.

One strategy for helping learners to use their existing knowledge to make sense of the above statements is to (1) design instructional situations which allow learners to see how values upon which our country was founded affect them personally, and (2) show how the outcome of the Civil War could have affected their lives. We might first design learning experiences which would help learners understand the effect of our country's basic values upon their everyday lives. Such experiences could be organized around issues such as: "How might your life be different if certain human rights were taken away?" And "what effect would the reintroduction of slavery have upon your life?" Many types of learning activities such as role playing, skits, discussions, and readings about the Civil War and about civil rights could be designed which would require the learners to use their existing knowledge to understand how their lives are affected by these values. Once the learners understood the personal relevance of these values, this knowledge would provide the background necessary to understand how their lives might be different if the Civil War had not occurred. Now a statement such as "the war was fought to preserve the values upon which our country was founded" can have personal meaning to the learners. They have used their existing knowledge to create that meaning.

This task of making the historical events personally relevant is only one of many methods of engaging the learner in the mental activities necessary to create the desired new knowledge. There are an infinite number of ways in which we can encourage learners to engage in these sorts of mental activities. The basic requirement is simply that the situation be arranged so that the learners are able to use their existing knowledge to make sense of their instructional experiences. If the current experiences do not easily relate to relevant aspects of their existing knowledge, learners have little choice but to learn the material by rote.

Frequently, instructional tasks and materials actually interfere with the mental activities necessary for learning. The learner is often lead away from these mental activities and directed to the task of making a mental copy. Ironically, the more difficult the material is to memorize, the more the learner will be led away from the mental activities which would allow her/him to understand it. That is, as more time and effort are spent on the task of memorization, less is left for the task of understanding. Often, this means that the learner is deprived of her/his tools for learning when s/he most needs them. Consider once again the array in Figure 11-2. Katona (1940) asked two groups of subjects to examine this array of 24 numbers. One group was given three minutes to memorize the array by repeating groups of three numbers over and over. The second group was given three minutes to discover some pattern or structure in the array. The structure upon which the array is based can be described as follows. Beginning at the lower left corner, add 3 to 5 to produce 8, and four to 8 to produce 12, and three to 12 to produce 15. This adding of 3 and 4 in alternation is the pattern of regularity which underlies the array. Katona found that most adults would discover this structure within the 3 minutes allowed. Subjects asked to memorize the array by rote also were able to successfully accomplish their task within three minutes. After a three-week delay, Katona asked both groups to reproduce the array. None of the subjects asked to memorize the array were able to correctly reproduce it. On the other hand, 23% of the subjects asked to discover the structure in the array were able to reproduce it correctly.

Discovering the structure (meaning) of the array helped the subjects reproduce it later, even though they had not been instructed to remember the array. The memory group was not provided a means for relating the numbers to their existing knowledge. They did not make sense of the array in terms of their existing knowledge, they simply made a mental copy of the numbers in the array. Discovering the alternating addition of 3 and 4 is important. This pattern or regularity relates the numbers in the array to each other. The array is no longer a meaningless list of 24 single numbers or 8 triplets. When the principle is known, the numbers become meaningful components of a logical system of relationships. The numbers 1 and 2 in the bottom row now form the number "twelve" which fits between 8 and 15. The array now makes sense as a unit or whole, that is, as a system of relationships. This system of relationships relates readily to the learners' existing knowledge, i.e., the alternating addition of 3 and 4. The array or the experience of the array has been made meaningful in terms of the learners' existing knowledge. Instructing the memory group to repeat the numbers in groups of threes prevented these subjects from relating the array to their existing knowledge, i.e., from making sense of the array in

terms of what they already know.

To this point we have considered a basic implication for instruction derived from our characterization of human learning. We have also discussed two conditions which are prerequisites to the accomplishment of this task. Finally, we will discuss a new goal of instruction derived from our characterization of learning.

This goal is the integration of the learning materials into the existing knowledge-structure of the learner. By this, we mean that learners interpret the learning material in terms of what they already know, thereby producing new knowledge which relates or has relevance to their existing knowledge. Rote memorization does produce new knowledge. But, as we have seen, this new knowledge may not be related to existing knowledge in a useful way. Often this knowledge exists as isolated bits of information which seem unrelated to other things we know and to most of our own experiences.

A child who is lead to figure out that air takes up space by blowing up balloons and bicycle tires or by submerging upside-down drinking glasses into water will have a more useful type of knowledge than will a child who has memorized a definition of matter and a list of instances of the concept.

The new information the learners acquire will be related to their existing knowledge of air, balloons, the action of blowing or pumping, tires, water, and glasses. This is just the beginning of a long list of relationships which are being acquired from the learners' activities.

It is more likely that this new knowledge will be useful to the learners in other situations involving balloons, tires, and things being submerged in water. This is true because of the relationships which were developed during the learning activities.

Repetition and drill, therefore, must do more than build replicas of the learning material. Practice and repetition must also be designed to help the learners to usefully integrate the new information into their existing knowledge. When the learners are able to make sense of the learning materials in terms of what they already know, this process of integration is off to a good start.

CONCLUSION

Learning does not have to involve relating new content to previously-learned content and/or to previously integrated experience. However, meaningful learning does necessarily involve such a process.

This insight into the nature of meaningful learning has several implications for the design of materials and for the development of instruction.

In order to facilitate the integration of the new content into the already-existing cognitive structure, the designer or developer must know what the existing cognitive structures of the target population are like.

Further, the assumption is unwarrented that the target students will all have the same cognitive structure, or that the "average" cognitive structure will be adequately representative of each individual within the target group. Individual differences in past experience and in the conceptual field this experience has been imbedded within, must be taken into account just as surely as must differences in intelligence or in cognitive style.

The new content can almost always be related to the existing structure, but in order to do this, the level of abstraction might have to be modified. Also, intervening material might have to be introduced as a sort of bridge in order to link existing structure to the new content. Examples of such links are advance organizers, field trips, laboratory experiments, films, and value-clarification sessions.

Not only must new content be relatable to existing cognitive structure, but this linking must be done in such a way that the connections are obvious to the student.

Therefore, special efforts should be taken to point out the relationships involved, using either examples, visual or textual cues, or direct statements of the relationships.

Since meaningful knowledge is actively related to, and ot passively absorbed into, the existing structure, the process of learning is an activity. It is not necessarily a physical activity; one can learn meaningfully from lectures as well as, or sometimes better than, from laboratories or field trips. But it is necessarily a mental activity, and so involves the use of cognitive strategies. Such strategies are individually devised by the student, with a great deal of diversity existing among students. The process by which the new content is integrated into existing cognitive structure, therefore, is an individual matter. Teaching should facilitate this process, should even direct it in a general sense, but should never dictate it.

Three methods are currently available, or becoming available, for facilitating the integrating process. First, new content can be presented through modes which are compatible with strategies which students already use (ATI and cognitive style technologies). Second, content can be presented in units which can be selected and ordered independently, and these selection and ordering operations can be left up to student (learner control). Third, students lacking appropriate strategies (or possessing inappropriate ones) can be taught new strategies (learning-to-learn procedures and student-development technologies).

In any case, material should be designed in such a way that new content can be seen as meaningful in terms of already-existing knowledge. This indicates that the language, whether it be written or spoken language or visual language, body language or mathematical language, should be presented in a vocabulary and grammatical struc-

ture, and with a degree of redundancy, which is appropriate to the existing cognitive structure. Words known to convey one meaning to the students for example, should not be used to transmit another meaning without the use of a cue-structure to alert the students to the new meaning.

Most important, with respect to language, is that students do not integrate content meaningfully by reproducing in their cognitive structures an exact copy of the mediating material in which the content was embedded when they encountered it. They instead abstract the meaningful content and restructure or reconstruct it in an easily-retrievable form so as to store it compatibly with existing meaning within the cognitive structure.

Therefore recall in the form of memorized lines, memorized formulas, page numbers or the names of authors (a favorite device for qualifying exams) should not be expected to result from meaningful learning, and should not be used as a measure of such learning. Further, the pressure of directions to learn such material can be expected to call forth a different set of cognitive strategies from the student which will not only result in non-meaningful learning of these materials, but will also prevent their being learned meaningfully, at least at that time.

Three principles should always be remembered when designing instruction: (1) New content can be meaningfully learned only when the student can relate this content to already-existing cognitive structure in a meaningful way. (2) The understanding of content is an activity of a constructionistic nature which is carried on by the student using cognitive strategies. (3) Students vary greatly in terms of the cognitive structures they possess and the cognitive strategies they exercise.

From these three principles it follows that teaching and instructional design are processes which facilitate the integration of new content into existing cognitive structure; they must begin by ascertaining the existing structures and strategies and they must proceed by embedding new content within material which is compatible with these beginnings.

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